A short survey instrument to segment populations according to their attitudes toward science: scale development, optimization and assessment

Füchslin, Tobias ; Schäfer, Mike S ; Metag, Julia

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Developing and Testing a Short Survey Instrument to Segment Populations according to their Attitudes towards Science

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Abstract
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Keywords: methods, audience segmentation, survey, attitudes towards science, science communication, Switzerland.

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1. Introduction: Survey Research, Segmentation Analyses and the Need for Short(er) Survey Instruments

Representative surveys on public perceptions of and attitudes towards science have a long tradition in many countries (for an overview, see Besley, 2013). Accordingly, a large number of survey instruments has been developed to assess, for example, people's "scientific literacy" (e.g. Kawamoto, Nakayama, & Saijo, 2013; Miller, 1983), their trust in science (e.g. Hendriks, Kienhues, & Bromme, 2015), their general reservations and beliefs about science (e.g. Bauer, 2016), or their preferences about the relation between science and society (e.g. European Union, 2013; National Science Board, 2018).

Some of these instruments refer to clearly established concepts that have a history of extensive scholarly debates about different theoretical approaches, the adequate measurements, their validity, their shortcomings and their potential improvements. This is true, for example, for measures of scientific literacy (cf. National Academies of Sciences, Engineering, and Medicine, 2016; Pardo & Calvo, 2004), and for measures of trust (cf. Hendriks, Kienhues, & Bromme, 2016; Schäfer, 2016). Other established measurements do not stem from such concise scholarly analysis and conceptual work. For example, measurements of the relation between science and the public that are often used in surveys (e.g. European Union, 2013; Wissenschaft Im Dialog, 2015) refer to a much broader scholarly debate about this relation, ideas of a potential participation of citizens, and the societal legitimation of science (see, e.g., the debates in Bucchi & Trench, 2016; Irwin & Wynne, 2003). In other words, they relate to general topical themes in the literature rather than dedicated conceptual work.

The breadth of available survey instruments is a clear positive, as it allows for the detailed analysis of science-related perceptions and attitudes across varying research interests and theoretical perspectives. Many of these measurements are widely used, e.g. in the international Eurobarometer surveys (European Union, 2013) or in the Science and Engineering Indicators in the United States (National Science Board, 2018) .

In addition, such perceptions and attitudes, captured via representative surveys, are often used in subsequent analyses, for example in segmentation analyses. Segmentation analyses "divide the general public into relatively homogeneous, mutually exclusive subgroupings" (Hine et al., 2014, p. 442), most often using quantitative, representative survey analyses with probability samples as the "gold standard" (Hine et al., 2014, p. 452). They have proven to be useful in many fields – such as social marketing (Yankelovich & Meer, 2006), environmental communication (Hine et al., 2014), health communication (Maibach, Roser-Renouf, & Leiserowitz, 2008) or political science (Sosnik, Fournier, & Dowd, 2007) – and have also been introduced in science communication (Guenther & Weingart, 2017; Kawamoto et al., 2013; Schäfer, Füchslin, Metag, Kristiansen, & Rauchfleisch, 2018).

These studies differ somewhat in the goals they ultimately pursue when applying the results of their segmentations – e.g. enhancing public communication of scientific results (e.g. State Government of Victoria, 2011), tracking the development of audience groups over time (e.g. Department for Business, Innovation & Skills, 2011; 2014), discovering cross-national differences (e.g. Liu, Tang, & Bauer, 2012; Mejlgaard & Stares, 2012), or building a basis for message design through additional analysis of communication channels (Metag, Füchslin, & Schäfer, 2017), or identifying interesting sub-populations for further research (e.g. Burns & Medvecky, 2018). But the aim of the segmentations themselves in these studies is usually very similar: They aim to distinguish groups among populations which are homogenous with regard to relevant characteristics – mostly with regard to "psychographic" variables such as perceptions and attitudes towards a specific issue.

Segmentation studies, particularly if they combine segmentation with an additional analytical step, can struggle with the available breadth of science-related survey instruments, however: Based on a long tradition of survey research assessing science-related attitudes, large number of respective variables has been used, and no commonly agreed upon set of variables to assess attitudes towards science exists (Besley, 2013). This is associated with two main problems for science-related segmentation research:

- First, identifying the relevant variables for segmentation can be a challenge. Many segmentation studies do not rely on specified theoretical models and use an "atheoretical whatever-works approach" (Hine et al., 2014, p. 447) instead. Others base their segmentation analyses on several concepts, including, for example, scientific literacy as well as reservations and beliefs and interest regarding science (Liu et al., 2012). As a result, both kinds of segmentation studies include a large amount of variables into their analyses (Department for Business, Innovation & Skills, 2011; Kawamoto et al., 2013). But survey time is often scarce, and therefore, scholars can be faced with a tradeoff between breadth and efficiency, i.e. between being "concise and informative" (Swim & Geiger, 2017, p. 568).

- Second, the results of different segmentation studies are sometimes hard to compare. While the respective studies might use similar names for the segments they eventually identified, these are often based on different survey items (such as Leiserowitz, Maibach, Roser-Renouf, & Smith, 2010; Metag et al., 2017). If one research group intended to build on another's segmentation, they would have to include the same high number of variables, which conflicts with the scarcity of survey time.

As a result, science-related segmentation analyses consist of many one-off segment solutions that are based on different and broad sets of variables which cannot be compared or easily reproduced without a large commitment of resources. We see two solutions for these problems:

- On the one hand, researchers could either try to eliminate the problem through "theory-driven optimization" of their analyses, identifying the most relevant theoretical concepts in the field and developing adequate and valid measurements. This would certainly be a worthwhile endeavor. But many different survey items are already available, and many of them are embedded in longitudinal surveys (e.g. Eurobarometer and Science & Engineering Indicator surveys) which provide researchers with comparable data over longer time-spans, making if difficult to revise these surveys following a strict conceptual principle deductively. Still however, if researchers in the field would agree on a core set of concepts, comparability across studies would be guaranteed and survey time could then be optimised.
- On the other hand, researchers have tried to remedy the outlined problems through "statistics-driven optimization" (e.g. Swim & Geiger, 2017) on a case by case basis. Larger studies could then provide initial segmentation solutions

whose measurement can subsequently be made more efficient (i.e. “shorter”) and therefore more easily adopted by future studies.

Researchers using segmentation analyses in fields like climate change communication have already employed the second approach. They have made efforts recently to develop shorter survey instruments that allow researchers to establish population segmentation with acceptable levels of accuracy, yet using less survey time and increasing the chance to have comparable data sets and results. Maibach, Leiserowitz, Roser-Renouf, and Mertz (2011), in a study that inspired our analysis, introduced and tested a shorter, 15-item survey tool to assess the segmentation of the US populations according to their attitudes about climate change. Swim and Geiger (2017) proposed a seemingly radical approach, a “one-item scale”, for the same topic, describing the segments found in earlier studies to respondents and asking them then to place themselves in one of them. Both studies were able to show that survey instruments could be significantly shortened without losing much of their analytical accuracy. Maibach et al.’s 15-item instrument, for example, could reattribute 83.8% of all cases correctly compared to the results of the ”Global Warming’s Six Americas” study. Swim & Geiger’s one-item instrument also proved to be highly correlated with the original 36-item instrument, but showed significant differences in segment attributions for three of the six groups.

Since many national surveys on public attitudes toward science exist, are unlikely to unify their concepts and measurements, and are used for segmentation analyses, we set out to follow the second, statistics-driven, approach as well: We propose a short survey instrument and assess its accuracy. Therefore, we firstly ask

- *RQ1: How do shorter survey instruments affect segment attribution accuracy in the case of perceptions of and attitudes towards science?*

In addition, we assess the predictive power of segment affiliation with regards to five selected behavioral variables – science-related media use regarding television, newspapers and magazines, and online sources; people's willingness to engage politically on science-related issues, and their frequency of talking about science and research with friends and acquaintances. – and the changes of this power depending on the scope of the survey tool.

- *RQ2.1: What is the predictive power of segment affiliation regarding these behavioral variables?*
- *RQ2.2 How is this predictive power affected by the shorter survey instruments?*

Afterwards, we discuss how future studies can adopt our short survey instrument and, more importantly, how similar procedures could also be used by other researchers to make segmentation analyses in other contexts more efficient and accessible.

2. The Reference Study: Identifying the Different Audiences of Science Communication in Switzerland

Our analysis relies on a segmentation study from Switzerland, which assessed the Swiss' perceptions of and attitudes towards science as well as their science-related patterns of information and media use (Schäfer et al., 2018). The study's design, its measurements and findings have to be shortly introduced before we can develop a short survey tool based on its data.

2.1 Data

The data stems from a representative, national survey – the "Science Barometer Switzerland" (www.wissenschaftsbarometer.ch) – conducted in 2016. Based on public telephone listings (90% landlines, 10% mobile), households were randomly selected, household members chosen according to sex and age quotas, and interviewed using computer assisted telephone interviews (CATI). 1,051 respondents participated (651 from the German-, 200 from the French- and 200 from the Italian-speaking parts of the country). The final sample was weighted regarding region, gender, age, education, occupation and household size.

2.2 Measurements

Faced with the breadth of variables in nationally representative surveys, the reference study covers a broad range of well-established measurements of peoples' perceptions of and attitudes towards science (cf. Appendix 1). This approach mirrors previous segmentations (Department for Business, Innovation & Skills, 2014; Kawamoto et al., 2013) regarding science. Firstly, cognitive, affective and conative aspects of attitudes towards science were assessed:

- To capture the *cognitive aspect*, respondents' knowledge about science was measured, using a quiz format (Kawamoto et al., 2013; Miller, 1983; Miller & Pardo, 2000).[1] In addition, we asked for respondents' interest in science (e.g. BBVA foundation, 2011; Department for Business, Innovation & Skills, 2014; European Union, 2010).
- The *affective aspect* was assessed by asking respondents for their trust in science (Lee, Scheufele, & Lewenstein, 2005), and for their assessment of whether they think science plays an important role in their lives.
- The *conative aspect* was captured by asking whether respondents search for information about science actively, and whether they would like to be personally involved in a research project once (Wissenschaft Im Dialog, 2015).

[1] As this format has been criticized e.g. Pardo and Calvo (2002, 2004), the format was adapted to include questions about arts and humanities in addition to the (natural) sciences, to include both textbook and applied scientific knowledge, and to also include a question about the process of science. Easier and more difficult questions (according to the correct number of answers in previous surveys where available) were mixed. And the dichotomous "correct–false" answer format that is often used was switched to a format allowing respondents to indicate the level of certainty in their answers Pardo and Calvo (2004, 223f.). These changes were crosschecked both with a recoded, traditional "right"/"wrong" scale for all 11 questions and with a recoded version containing only those five questions which were taken verbatim from earlier studies.

Secondly, respondents' "reservations and beliefs" with regards to science were assessed through a set of questions that has been used in many international surveys before (e.g. European Union, 2010; National Science Board, 2018). "Beliefs" capture the hopes and positive aspects people associate with science and scientific developments. "Reservations" encompass to what extent they think that science has limitations or that science and research can also have negative consequences. The Science Barometer Switzerland used an abbreviated variant of the version developed by Prpić (2011).

Thirdly, respondents' attitudinal preferences (i.e. subjective norms) with regards to science and science communication were assessed. Questions from different surveys were combined which asked respondents about their preferred relation of science and society (Besley, 2013; European Union, 2010; Nisbet et al., 2002, p. 591; Wissenschaft Im Dialog, 2015). In contrast to the reservations and beliefs, this relation tackles the different ways science influences other systems of the society, such as politics or the public sphere, and is similarly influenced by or dependent on these systems, e.g. whether they think science should be funded even if it had no immediate use, whether it should be publicly funded, whether science should influence politics, whether scientists should inform the public about their results etc. Furthermore, people's informational norms with regards to science were assessed (Kahlor, Dunwoody, Griffin, & Neuwirth, 2006), i.e. whether they think that it is important to be informed about science and research.

In addition, we measured a number of non-attitudinal variables that were not used to reconstruct segments of the Swiss population but to describe them in a second step. They include sociodemographic characteristics (age, sex and education, (Besley, 2013; Nisbet et al., 2002; Roten, 2004), religiosity (OST & The Wellcome Trust, 2001), and political orientation (cf. Nisbet et al., 2002), as well as reports of of media and information use behavior with regards to science

2.3 Results

20 variables capturing the Swiss populations' perceptions of and attitudes towards science were used in latent class analysis[2]. BIC values showed two- or three-cluster solutions to be unfavorable and all other solutions were on similar levels. As the four-cluster solution offered the clearest interpretation, it was used for further analysis and can be briefly summarized as follows (cf. Schäfer et al., 2018):

1. The *„Sciencephiles"* (n=292; 27.8%) include people with high interest in, high knowledge of, and very positive attitudes and beliefs towards science. They think that science plays an important role in their lives and are highly supportive of science. Regarding the promises of science, they are the most hopeful and least critical of all segments.
2. The *"Critically Interested"* (n=181; 17.2%) match the *"Sciencephiles"* in their knowledge of, attitudes towards, and support of science. The main difference is that they trust science considerably less, and have stronger reservations regarding science's promises. For example, they clearly favour research constraints and think that humanity relies too heavily on science in general.
3. The *"Passive Supporters"* (n=437, 41.5%) are the largest group. Their interest, attitudes, and trust regarding science are moderate. While not as strong as the former two groups, however, they are still supportive of science. Overall they share some hopes and reservations, again on moderate levels. For example, they think science improves our lives, but also that scientific research should have clear constraints.
4. The *"Disengaged"* (n=141; 13.4%), the smallest segment, have the lowest, albeit still moderate support of science. They think, however, that science does not play an important role in their lives, and have the lowest knowledge of, interest in, and

[2] We ran the analysis with LatentGold 5.1 Vermunt and Magidson (2016). 5,000 random sets of starting values were entered into the algorithm to ensure validity and robustness of each solution.

trust in science. Their hopes and reservations regarding science are similar to the *"Critically Interested"*, but on a slightly less pronounced level.

3. Developing and Testing a Short Survey Instrument: Results

The following analysis aims to develop a shorter survey instrument as an alternative to the 20-item version used in the reference study, and to test how much its accuracy decreases compared to the full version.

3.1 Construction and comparison of short survey instruments

In order to develop a shorter scale for identifying attitude segments, we first assess the predictive power of each of the 20 items used and, second, evaluate for each of the shortened instruments how many of the original cases were correctly attributed to their original segment.

The four-cluster solution of our segmentation analysis can be fully described by a linear combination of the 20 attitudinal items used in the reference study. Based on this survey instrument, researchers can calculate the likelihood of cases to belong to one of the four segments. We provide the SPSS syntax containing the equation to replicate our four-cluster solution in the appendix.

It is also possible to describe the solution with a linear equation based on a subset of items. However, a shorter survey instrument reduces attribution accuracy, albeit to different degrees depending on the predictive power of the different items. Regarding RQ1, we calculated equations describing our four-segment solution, first based on 20 items, then on 19, 18, and so on, down to one item. These survey instruments were constructed according to the items' predictive power for segment attribution (see Table 1). Accordingly, the one-item instrument is based on the best predictor *(1. "Science and* *research play an important role in my life"*), the two-variable instrument on the best two predictors (+ 2. *"I specifically search for information about science and research"*), and so forth.

[Table 1 about here]

We applied each equation to the cases in our original data set to compare how accurate the predictions based on shorter instruments are in comparison to the original four-segment solution. For each instrument, Figure 1 shows how many of the original cases were correctly attributed to their original segment.

Using the ten best predictors results in 92.1% of all cases still being attributed in accordance with the original 20-item solution. Instruments based on the best twelve or more variables produce more than 95% correct attributions. In turn, accuracy drops more quickly for instruments using fewer than the best ten predictors. As expected, the instrument based on the sole best predictor yields the lowest accuracy with 59.5%. Thus, we argue that, based on statistics alone, a survey instrument incorporating only ten out of the original 20 items can be used to reproduce the attitudes segments reliably.

As an additional benefit, the ten-item solution also covers all of the main attitudinal categories such as cognitive, affective, and conative attitudes or people's "reservations and beliefs" with at least one item. Interestingly, however, scientific literacy, one of the best conceptualized instruments in science communication, was not found to be one of the ten most important predictors.

[Figure 1 about here]

3.2 Regression-based validation of the short survey instruments

Segmentation analyses reconstruct divisions between groups of people that are connected to other factors – to sociodemographic profiles (e.g. Kawamoto et al., 2013), to peoples' general values (e.g. Roser-Renouf, Maibach, Leiserowitz, Feinberg, & Rosenthal, 2016), to behavioral intentions (e.g. Maibach et al., 2011) or information use (e.g. Metag et al., 2017). Similarly, our previous analyses of the Swiss case have shown that the four identified segments differ not only in their attitudes towards science, but also with regards to a broad range of media and information variables and sociodemographics (cf. Schäfer et al., 2018). These differences, however, were only assessed on a bivariate level.

To further assess the short survey instruments proposed here, we used multivariate models to evaluate the predictive power of segment affiliation regarding such topically related dependent variables (RQ2.1), and to subsequently assess how this predictive power is affected by the shortening of the survey instrument item by item (RQ2.2).

To answer RQ2.1, we tested the influence of segment membership on five separate dependent variables (cf. Tables 2 and 3). The first three models focus on people's contact with science and research through the three most relevant science media sources in Switzerland: Swiss public television (*1="never" ... 5="very often"; m=2.86, sd=1.2*), daily and weekly newspapers and magazines (*1="never" ... 5="very often"; m=3.28, sd=1.22*), and online media *(using an index of seven online sources; 1="never" ... 5="very often"; m=2.06, sd=0.81*).[3] For the next two models, we chose two behavioural variables: people's willingness to vote on science-related issues *("When the issue is science-related, I always participate in popular votes"; 1="do not agree at all" ... 5="agree strongly"; m=4.03,*

[3] Each media source was measured via a single survey item. While we had a similar one-item variable available for overall "internet" contact with science, we took advantage of an additional question in which we asked respondents for their online use in more detail. We could build an online media index (α = 0.80) consisting of the use of following sources to get in contact with science and research: online outlets of newspapers and magazines; online archives of television and radio channels; institutional websites (scientific, government, organizations); Facebook; blogs or message boards; Wikipedia; YouTube or similar video platforms.

sd=1.23) and people's frequency of talking about science with their friends *("How often do you talk about science and research with friends and acquaintances"; 1="never" … 5="very often"; m=2.47, sd=1.08*).

[Tables 2 and 3 about here]

As our independent variables, we chose a basic set of demographics and value predispositions established in science communication research (e.g. Anderson, Brossard, Scheufele, Xenos, & Ladwig, 2014; Shih, Scheufele, & Brossard, 2012): age *(m=46.33, sd=17.9)*, gender *(50.8% female)*, highest education level *(43.3% tertiary education, 44.9% secondary education)*, political orientation *(1="far left" ... 7="far right", m=3.64, sd=1.28)*, and religiosity *(1="not religious at all" ... 5="highly religious", m=2.72, sd=1.25)*. Additionally, we included people's attribution to one of the four segments *(reference category = "Passive Supporters")* based on the original solution which included 20 items.[4]

- Model 1 (*adj.* R^2 *= 5.2%*) shows positive correlations of age, education and religiosity with people's contact with science and research through Swiss public television. The three segment variables do not show any significant[5] relation. Overall, the independent variables are only able to explain about five percent of the dependent variable's variance.
- Model 2 (*adj.* R^2 *= 11.3%*) displays a significant relations of age (positive) and political orientation (negative) with people's contact with science and research through daily and weekly newspapers and magazines. This time, segment variables prove to be some of the strongest predictors: Being a *"Sciencephiles"*

[4] Except for normal distribution of residuals in model one and four, all assumptions of linear regression were met in the other three models. Due to the large sample size, however, the linear models should be robust enough to overcome these slight distortions.

[5] We use "significant" as p<0.05

has a significantly positive correlation with print media contact, while being a *“Disengaged”* is negatively related.

- Model 3 (*adj.* R^2 *= 26.6%*) shows that younger respondents, men and respondents with higher education come significantly more often into contact with science and research online. All segment variables turn out to be significant predictors for respondents’ use of online media. Attribution to the *“Disengaged”* segment correlates negatively with the use of these media, while belonging to the *“Sciencephiles”* and the *“Critically Interested”* is positively correlated.
- Model 4 (*adj.* R^2 *= 17.4%*) depicts positive correlations of education and age with people’s willingness to participate in public votes on science-related issues. Furthermore, all segments prove to be significantly linked to science-related voting decisions: Belonging to the *“Sciencephiles”* or *“Critically Interested”* has a positive association, while attribution to the “Disengaged” has a negative one.
- Model 5 (*adj.* R^2 *= 24.8%*) shows that younger and more educated people are significantly more likely to talk about science and research with friends and acquaintances. The three strongest predictors, however, are affiliations to the three segments. Just as in model 4, attribution to the *“Sciencephiles”* and *“Critically Interested”* is positively related and attribution to the “Disengaged” negatively.

To answer RQ2.2, i.e. to assess how this predictive power is affected by shorter survey variants, we compared how the five explanatory models change when replacing the full segment attributions based on 20 items with those based on the shorter survey instruments, going from 19, 18, 17 items down to segment attributions based on just one item. Figure 2 shows the percentage of adjusted explained variance the segment attribution variable contributed to predicting one of the five dependent variables (models 1 to 5).

[Figure 2 about here]

- For model 1, the segmentation variables barely offer any added explained variance. It ranges around 0.5% across all twenty solutions. This is not surprising, as the full model previously showed that they do not have any significant influence on people's contact with science through television.
- Results across twenty segment solutions are more telling for model 2, where the gained R-squared remains stable around 5% (+/- 0.5%) from the full, 20-item instrument down to the seven best predictors. After that, it falls as low as 2.2% at the two-item solution. Despite these larger fluctuation for the smaller instruments, the influence of attribution to the *"Sciencephiles"* and *"Disengaged"* shrinks but remains significant in all instruments. Only at the one-item instrument, attribution to the *"Critically Interested"* turns statistically significant.
- For model 3, the gained R-squared remains even more stable than in the previous two models, accounting for approximately 11,2% (+/- 0.8%) from the 20- down to the two-item solution. In line with this observation, the segment indicators remain significant influences throughout all 20 solutions.
- For model 4, the explained variance added by the segmentation variables ranges between 14.8% (7-item-scale) and 8.1% (2-item-scale). From 20-item to the eight-item instrument, the explanatory power remains constant around 12.5% (+/- 0.7%). In all cases the segmentation variables do add a significant gain in explained variance to the model. The strong correlation of attribution to the *"Sciencephiles"* and the *"Disengaged"* remains significant across all versions. The link to belonging to the *"Critically Interested"* only drops below statistical significance for the scales based on two to eight items.

- For model 5, segment variables add around 20.2% (+/- 0.8%) of explained variance to the models based on solutions with 20 down to five items. The smallest four solutions display a more random gain of R-squared, ranging from 22.4% (four-item solution) to 14.8% (one-item solution). The three segment variables, however, remain their significant correlation with people's frequency of talking about science with friends across almost all twenty models. Only at the last model, based on the one-item solution, belonging to the "Critically Interested" loses its significant correlation.

Overall, these results show that the statistical models produce stable results even when the original 20 segmentation variables are replaced by solutions with fewer items. In all five models, the explained variance gained by the segment variables remains stable down to the model based on eight-items. Results fluctuate more strongly for the smaller solutions. Such consistent results make sense, as at least 80% of cases receive an identical attribution. The more incorrect segment attributions a short survey instrument contains, the more it is up to chance in which segment an individual ends up, which randomly distorts all further analyses.

4. Discussion & Conclusion

Survey research on public perceptions of and attitudes towards science uses a breadth of science-related survey instruments. Many segmentation analyses, even though many of them share similar goals, have therefore used a high number of variables to identify segments of different populations which are homogeneous in their attitudes towards science. This makes it difficult for subsequent studies to build on these solutions, as they would have to use similarly extensive sets of variables to reconstruct these segmentations. While it would be desirable that science communication scholars agree on a smaller number of theoretical concepts in the first place (cf. Bauer, 2012), we proposed a more pragmatic statistical optimization, and assessed to what extent shorter survey instruments would allow researchers to establish population segmentation with acceptable levels of accuracy while devoting less survey time to capture the respective items. Using survey data from Switzerland, we analyzed how shorter survey instruments affect segment attribution accuracy, and in how far the predictive power of segment affiliation is affected by shorter survey instruments.

Results have shown two robust findings: First, removing the items with the weakest influence on segmentation only marginally affected the accuracy of the attribution of respondents to attitudinal segments, up to a certain point. With half the number of original items – ten instead of twenty – we were still able to assign more than 90% of all respondents correctly to the same segments derived from the 20-item solution. Given that a larger drop-off in accuracy occurred after the 10-item version, we recommend that this 10-item version should be used in future studies. Not only is this solution statistically accurate, it also covers all the concepts included in the original solution: cognitive (one item), affective (two items), and conative (two items) attitudes; reservations and beliefs (three items); beliefs regarding the relationship between science and society (one item); and the informational norm (one item) (cf. Table 1 and Appendix). . Such future studies can employ the 10-item solution directly (cf. syntax in appendix) but would also be able to assess the accuracy of other, either longer and shorter versions of the original survey instrument based on our results.

Second, our results have also shown that segment affiliation can be a powerful behavioral predictor. Previous research already suggested this with regards to media and information use and other behavioral variables, and the reference study described above has indicated this as well. To assess the explanatory power of the shorter survey instruments, we provided additional regression analyses assessing the predictive power of belonging to a given segment on different media contact and behavioral variables while controlling for sociodemographic variables. Models for media contact with science – via television, newspapers and magazines, and online media–, and of lifeworld behavior – voting in science-related referenda and talking to friends about science – demonstrated that segmentation attributions are some of the most powerful correlates.

Only for one of the five dependent variables, people's contact with science and research through Swiss public television, segment variables did not have any relevant correlations. The otherwise strong correlations reflect that the solution contains many key measurements such as conative attitudes for behavioral outcomes and cognitive attitudes for media consumption to predict different outcome variables.

Furthermore, we showed that the application of shorter prediction instrument leads to results similar to those obtained with the 20-item version, again up to a certain point. For all five dependent variables, incorporating a shorter scale for segment prediction does not skew the results in a meaningful way. In all cases, the ten-item solution recommended above had a predictive power similar to the 20-item solution (+/- 0.8%). When comparing the ten- to the full 20-item solution, the three variables indicating respondents' attribution to the specific segments remained significantly correlated to all the five dependent behavioral variables we tested.

These results are encouraging for researchers aiming to build on established segmentation analyses and yet save survey time: respondents' segment affiliation with regards to attitudes towards science can be predicted well with a smaller set of items. In addition, there seems to be clear value in ascertaining group attribution, and it's worth doing so even when resources or survey time are limited. We provide our short survey instrument for other researchers; but more importantly, we hope that the general approach we have outlined in this article encourages future research to take advantage of this kind of evaluation when doing their own segmentation analyses, laying the groundwork for continued and comparative analyses.

It is important to highlight, again, that a statistics-driven optimization is not the only way of optimization. It would be even more valuable to the science communication community if scholars tried to conceptually identify the most relevant constructs (cf. Bauer, 2012). Such efforts should, on the one hand, also consider newer concepts such as "ordinary science intelligence" (Kahan, 2016), which extends the traditional measurement of scientific literacy (construct and process knowledge) by including quantitative reasoning and cognitive reflection abilities. On the other hand, they should revisit overlooked concepts from other disciplines such as people's "epistemic beliefs" (Chinn, Buckland, & Samarapungavan, 2011), which ascertain the way people belief knowledge to be structured (e.g. stable vs. tentative).

Nonetheless, our results and approach need further strengthening as well. Similar analyses using other datasets would be useful tests for the procedure proposed here, as would be additional tests of the predictive power of segment affiliation using other dependent variables or measuring similar dependent variables not only via one item, like we did for two of our three dependent variables (due to our own survey time constraints), with more elaborate measures. Importantly, testing short(er) survey instruments in other national contexts would be helpful. After all, Switzerland may be a peculiar case – a highly innovative country with excellent universities and a high degree of spending for tertiary education - and results in other countries may differ (cf. Guenther & Weingart, 2017 for South Africa; Kawamoto et al., 2013 for Japan).

Such additional tests would be worthwhile, however: while it is always recommendable to include as many of the original variables as possible in segmentation analyses, this will not always be feasible, or practical, in studies. Under these circumstances, being able to fall back on an alternative which is concise yet still informative would be helpful.

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Segmentation items	R^2	
1. “Science and research play an important role in my life”	0.4679	Proposed 10-item solution
2. “I specifically search for information about science and research”	0.403	
3. “It is important to be informed about science and research”	0.3498	
4. “How interested are you in science and research?”	0.3123	
5. “Scientific research should be publicly funded”	0.3041	
6. “Science and research make our lives better”	0.3036	
7. “I would like to partake in scientific research once”	0.3030	
8. “How high is your trust in science in general?”	0.2906	
9. “Science should have no limits to what it is able to investigate”	0.2752	
10. “Science and technology can sort out any problem”	0.2445	
11. “Scientific research is necessary even if there is no immediate application”	0.2314	
12. “Science will eventually provide a full picture of how nature and the universe works”	0.2006	
13. “Political decisions should be based on scientific findings”	0.1949	
14. “Scientists should inform the public about their work”	0.1820	
15. “The benefits of science are greater than any harmful effects it may have”	0.1400	
16. Index: Scientific Literacy	0.1238	
17. “People like me should be involved in decisions about the topics scientists research”	0.0577	
18. “Scientists should listen more to what regular people think”	0.0173	
19. “We rely too heavily on science”	0.0114	
20. “Science makes our ways of life change too fast”	0.0087	

Table 1: Segmentation variables of reference study ranked according to their predictive power for segment attribution

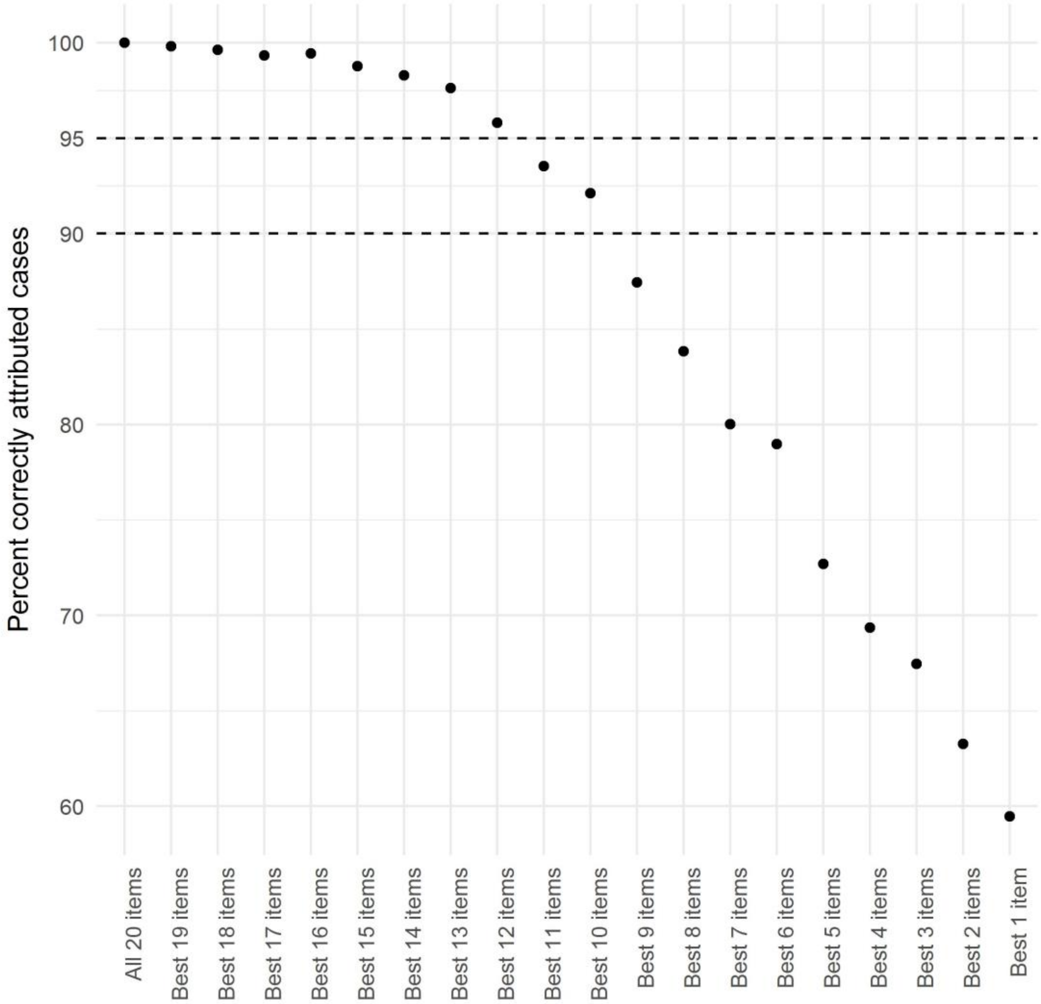

Figure 1: Percentage of correctly assigned cases based on different survey instrument lengths (20-item-instrument as reference).

	Model 1: National television contact			Model 2: Daily and weekly newspapers and magazines contact			Model 3: Online media contact		
IVs	*std. Beta*	*CI*	*p*	*std. Beta*	*CI*	*p*	*std. Beta*	*CI*	*p*
(Intercept)			<.001			<.001			<.001
Gender (*Female*)	0.04	-0.02 – 0.10	.215	0.01	-0.05 – 0.07	.720	-0.06	-0.12 – -0.00	.034
Age	0.16	0.10 – 0.23	<.001	0.19	0.13 – 0.26	<.001	-0.35	-0.41 – -0.29	<.001
Education (*Primary*)									
Secondary	0.15	0.04 – 0.25	.007	0.05	-0.05 – 0.15	.344	0.09	-0.00 – 0.18	.061
Tertiary	0.11	-0.00 – 0.22	.060	0.08	-0.02 – 0.19	.129	0.14	0.04 – 0.24	.005
Religiosity	0.08	0.02 – 0.15	.011	0.02	-0.04 – 0.08	.518	-0.04	-0.10 – 0.02	.156
Political Orientation	-0.03	-0.10 – 0.03	.281	-0.07	-0.13 – -0.01	.027	0.00	-0.05 – 0.06	.867
Segment (*“Passive Supporters”*)									
“Science-philes”	0.04	-0.03 – 0.11	.234	0.14	0.07 – 0.21	<.001	0.28	0.22 – 0.34	<.001
“Critically Interested”	-0.05	-0.12 – 0.02	.136	0.04	-0.02 – 0.11	.210	0.10	0.04 – 0.16	<.001
“Dis-engaged”	-0.04	-0.11 – 0.02	.177	-0.17	-0.23 – -0.10	<.001	-0.17	-0.22 – -0.11	<.001
Observations		971			969			958	
adj. R^2		.052			.113			.266	

Table 2: Linear regression models with effects on peoples’ overall contact with science and research through national television, daily and weekly newspapers and magazines, and online media.

IVs	Model 4: Willingness to vote on science-related issues std. Beta	CI	p	Model 5: Talking about science and research std. Beta	CI	p
(Intercept)			<.001			<.001
Gender (*Female*)	-0.02	-0.09 – 0.04	.461	0.00	-0.05 – 0.06	.925
Age	0.09	0.03 – 0.16	.004	-0.09	-0.15 – -0.03	.002
Education (*Primary*)						
Secondary	0.14	0.01 – 0.28	.041	0.09	-0.00 – 0.19	.056
Tertiary	0.19	0.05 – 0.33	.009	0.11	0.01 – 0.20	.036
Religiosity	-0.04	-0.11 – 0.02	.226	-0.02	-0.08 – 0.04	.489
Political Orientation	0.01	-0.06 – 0.07	.806	-0.02	-0.07 – 0.04	.599
Segment (*"Passive Supporters"*)						
"Science-philes"	0.20	0.12 – 0.27	<.001	0.31	0.24 – 0.37	<.001
"Critically Interested"	0.12	0.05 – 0.19	.001	0.21	0.15 – 0.27	<.001
"Dis-engaged"	-0.26	-0.33 – -0.20	<.001	-0.26	-0.32 – -0.21	<.001
Observations		842			975	
adj. R^2		.174			.248	

Table 3: Linear regression models with effects on peoples' willingness to participate in public votes on science-related issues and people's frequency of talking to friends and acquaintances about science and research.

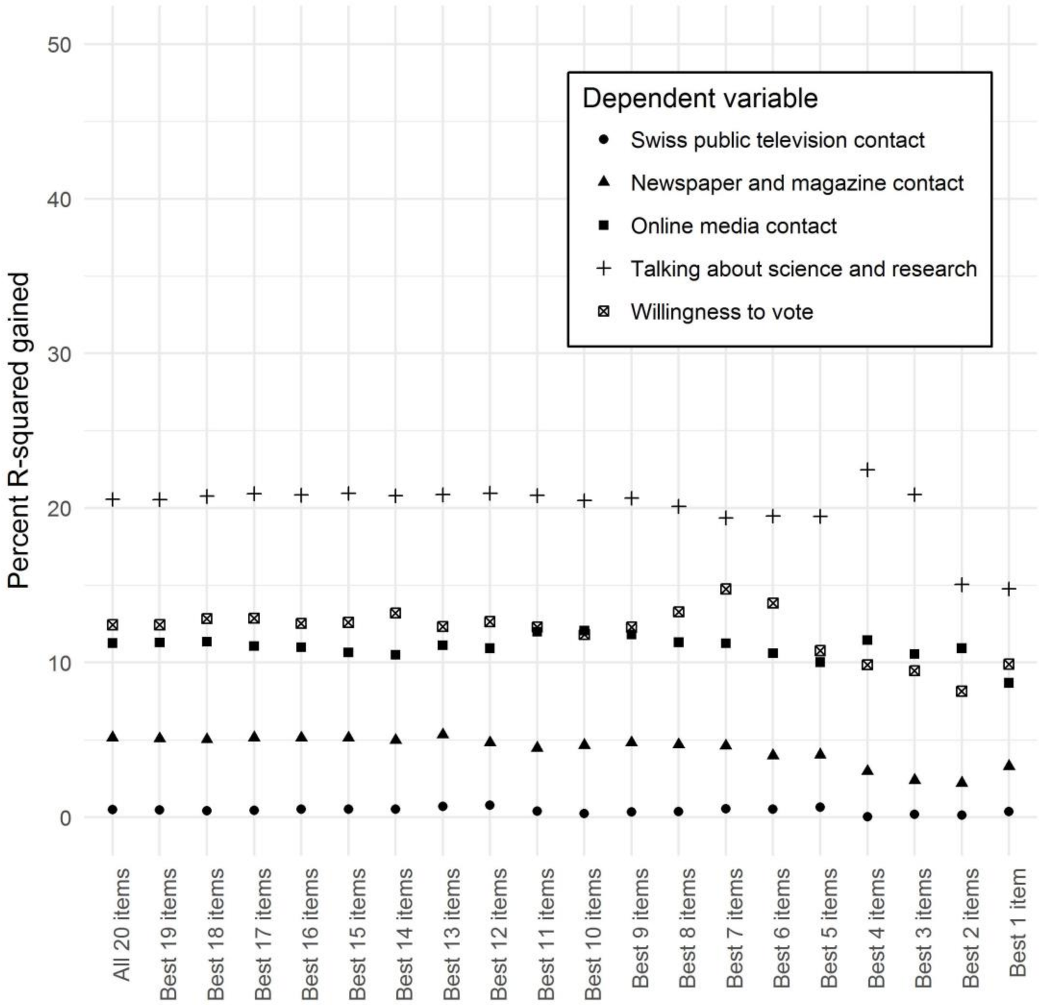

Figure 2: Percentage of adjusted explained variance added to the media contact and behavior models by including segment variables based on different survey instrument lengths.